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SCIENTIFIC-TECHNICAL PROBLEMS IN ELECTRIC-DRIVE AUTOMATION DURING THE CURRENT SEVEN-YEAR PLAN

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SCIENTIFIC-TECHNICAL PROBLEMS IN ELECTRIC-DRIVE AUTOMATION DURING THE CURRENT SEVEN-YEAR PLAN

[Following is the translation of an article by M. G. Chilikin and I. I. Petrov entitled "Nauchno-Tekhnicheskiye Problemy Avtomatizirovannogo Elektroprivoda v Tekushchem Semiletii" (English version above) in Avtomatika i Telemekhanika (Automation and Telemechanics), Vol. XXI, No. 2, 1960, pages 161-166.]

The grandiose plan approved by the XXI Congress of the CPSU for the development of the people's economy of the USSR in 1959-1965, envisages a broad-scale increase in the production of labor on the basis of increasing the electrification and automation of industry. Since the electric drive is the basic type of machinery drive, electrification determines the degree of mechanization of manufacturing. A direct relationship exists between the electrification of work and productivity: during the last ten years the productivity of work increased in the industry of the USSR approximately by the same percentage as the increase of its electrification.

By electric drive we mean a complex installation which transforms electrical energy into mechanical energy, which may be controlled electrically. In connection with this, the further development of electric drives should go in the direction of performing all forms and types of movements without the use of mechanical elements (rotary and translational; continuous, interrupted, pulsing, following; uniform, seldom or continuously varying according to a definite law or arbitrarily). The development of the electric drive should render possible the expansion of its functions in automatic control and regulation of production equipment systems (control of starting, reversing and slowing down of production machines; maintenance of constant speed, torque, power; control of production machines according to a certain program, etc.).

The science of electric drives was basically founded by Soviet scientists, and at the present time this branch of technical knowledge has been developed into an independent division of electrical engineering. Highly advanced electric drives have been developed and are widely used in

the industry of the USSR. The total volume of scientific research work being done in scientific research and development institutes, higher educational institutions, the design offices of manufacturing enterprises, and other organizations is, however, still inadequate. Many problems of electric drives, which are of great importance to the economy of the country, are not yet solved.

The development of a cheap variable-speed alternating current motor drive is one of the primary problems which has not been solved. In this respect, the development of simple and reliable methods of frequency control of a-c motors, particularly the development of a-c current supply sources with variable frequency become very important. The principal attention here should be given to the development and investigation of static frequency changers using ionic, electronic and semiconductor techniques.

Somewhat better results have been achieved in the development of variable speed a-c motor drives with choke control. In recent years, a number of such electric drives have been developed and supplied to the industry, and the scientific and engineering computation techniques have also been adequately developed for them. But the range of application of electric drives with choke regulation is somewhat exaggerated, and this has sometimes led to incorrect decisions in the choice of drives for industrial machines. Thus, for example, this drive was used without sufficient justification for excavating machines of medium capacity. Low engineering-economical characteristics and unreliability of service were the result. The Government Scientific-Technical Committee of the Council of Ministers of the USSR made a special decision recommending the discontinuation of equipping excavators with this electric drive, and the use of variable speed a-c motors instead. The application of this drive for railroad scale cars was also unsuccessful. Obviously, it is necessary to determine the correct limits of applicability of electric drives with choke regulation, with consideration of their relatively low performance coefficients for wide-range and prolonged speed regulation in industrial machines and the load characteristics of these machines.

A further investigation of the dynamics of the choke-regulated electric drive is needed, taking into consideration the nonlinearity of its separate components and problems of heating of the drive in cases of cyclic variable loads.

The intensification of manufacturing processes points to the necessity of developing electric drives with squirrel-cage asynchronous motors for manufacturing

equipment operating with frequent starts and reversings. This problem, however, remains unsolved. It is necessary to develop a modified series of asynchronous motor, based on the existing series and equipped with heat-resistant insulation and longer rotors calculated for a high switching frequency; design methods for these drives with frequent starts and reversals must be worked out alone. Special attention should be given to transient processes and to the problems of heating in these drives.

The state of the investigation of operating characteristics of a-c drives supplied with current from autonomous sources of equal power has advanced somewhat. But even here, many problems related to increasing the power of asynchronous motors driven by separate generators must be solved also. Special attention should be given to the problems of process dynamics in these drives.

Problems related to the application of synchronous motors for constant-speed or variable-speed industrial drives should be investigated further. The introduction of self-starting motors, and motors starting with dead-connected exciters has widened somewhat the field of application of synchronous-motor drives. But in spite of their specific properties and high performance indices, the synchronous motors are still not widely enough used. Their wider application for industrial-machine drives could considerably increase the coefficient of efficiency of electrical installations and ensure more rigid mechanical characteristics of the electric drive over a wider speed range. The application of motors with a shifting stator permits solution of the problem of shaft symphasing, etc. For the above reasons, research dealing with the investigation of new areas of application of synchronous motors operating with constant or variable speeds, and with problems of their automatic regulation should be of great interest. For example, the problems of economic speed regulation of synchronous motors by frequency variation, and problems of automatic control of excitation for motors subject to shock loads are of importance. A further investigation of transient processes in synchronous electric drives and development of scientific methods for calculating these processes are necessary.

Numerous problems of variable-speed d-c electric drives also require clarification. In the widely-used "generator-motor" (G-D) sets, only d-c motors withshunt excitation are used, andthese are less adapted to torque overloads than series or compound motors. The application of high-power semiconductor rectifiers, connected into series-excitation windings renders possible the construction

of a new type of set with improved dynamic characteristics. Analogous systems can also be designed with current feed from controlled mercury rectifiers (URV).

Substantial success has been achieved in development and application of electric drives with ionic rectifiers (for nonreversible variable-speed drives). A significant improvement in the dynamic characteristics of the "generator-motor" system is achieved by the use of variable mercury rectifiers for excitation of the system. But the development and application of these systems is progressing very slowly.

Considerable difficulties are encountered in the application of "mercury rectifier-motor" systems for reversible drives. In connection with this the further development and investigation of automatic regulation of ionic electric drives, where the ionic converter must be considered a part of the over-all control system, are of great importance. These systems must have a high-Q-factor and quick response, and provide for operation in the rectifying and inverting regimes with a low power consumption for control.

The development and investigation of ionic drive systems which increase the power factor over a wider speed control range, and of systems of automatic regulation of the power factor of ionic sets are necessary in order to ensure the most advantageous conditions of electrical energy supply to industrial enterprises.

Increasing use has recently been made of magnetic amplifiers in electric drives. They are used in "magnetic amplifier-motor" systems, in generator-motor systems for controlling generator excitation, for grid control of mercury rectifiers, and also as intermediate amplifying components.

The application of semiconductor amplifiers, which are used mostly as preamp stage together with dynamoelectric and magnetic amplifiers, has also expanded. But still the field of application of these new amplifiers is not yet distinctly defined. It is definitely necessary, however, to replace the dynamoelectric amplifiers in the drive systems with the more reliable magnetic and semiconductor amplifiers, which also have a longer useful life.

At the same time, it is necessary to work on problems of developing high power semiconductor rectifiers for "semiconductor amplifier - motor" systems, and for regulation of generator excitation in the "generator-motor" system. New automation equipment (dynamoelectric and magnetic amplifiers, semiconductor and electronic devices) renders possible the construction of highly efficient

control systems for electric drives which permit maximum usage of machinery and precise maintenance of a specified schedule of movements, etc. Here the so-called optimum control systems, which achieve a minimum operating time of the driven mechanism in the presence of limitations of path length, velocity, acceleration or heating, acquire special importance.

The investigation of transient processes in such basically nonlinear systems is very difficult. At the present time it is quite possible to solve these complicated problems by the methods of mathematical simulation, using analog or digital computers. However, these possibilities are very seldom used for the development of automatic electric drive systems. This can be explained on the one hand by the inadequate number of such computers available to the scientific-research and design organizations and, on the other, by the lack of scientific and engineering personnel acquainted with these methods of mathematical simulation. The training of engineers in the higher educational institutions to specialize in electric drives is also unsatisfactory. Up to the present time all textbooks on electric drives have been based on on the classical methods of investigation and do not pay adequate attention to the more modern methods, including methods of mathematical and physical simulation. In the laboratories of the educational institutions, no provision has been made for work with computing machines. In connection with this the most important problems requiring attention are:

1)Equipment of scientific research and educational institutes and design and other organizations with analog and digital computers;

2)Keeping the scientific and engineering personnel up to date in the fields of mathematical and physical simulation;

3)Further development of scientific-research work on transient processes in complex automatic electric drive systems constructed with the use of the latest automation equipment, and on modern, essentially nonlinear systems, which guarantee optimum transient processes in the electric drive;

4)Modernization of courses dealing with electric drives and related subjects in higher educational institutions in order to develop more modern methods of theoretical and practical analysis of electric drives;

5)Publication in the next few years, of textbooks on electric drives which provide a transition from old methods of investigation of the dynamics of electric

drives to the new methods, and including methods of mathematical and physical simulation.

Certain problems of multimotor electric drives are also unsolved. For example there is need for a further investigation of the electric-shaft system with variable ratios between the speeds of individual elements for assembly-line aggregates is required. The theory of nonsteady processes in electric drives with friction couplings between motors, and the problems of oscillation damping of an electric shaft system equipped with frequency converters and double-feed machines must also be developed. A general theory of the electrically-coupled multimotor drive for maintaining constant tension on the processed material in a continuous technological process has not been developed up to the present time.

Satisfactory attention has not been given to the manufacture and application in automatic electric drives of the various electromagnetic couplings including those with ferromagnetic charges. Their use may lead to the construction of efficient electric-drive systems, especially those adapted to smooth starting, acceleration of large inertial masses, torque regulation, speed regulation, etc. They can perform functions of brakes, dynamometers, location locks, torque limiters, etc. At present, electromagnetic couplings are relatively widely used only in machine construction. The experience gained in the manufacture of machine tools should be extended to other branches of the national economy. It is necessary to engage in several research projects directed toward clarification of the possibility of constructing efficient electric-drive systems with electromagnetic couplings for diverse types of production mechanisms.

For many years, different branches of industry, and in particular, the machine-building industry, have been advancing the problem of developing a drive for reciprocation or vibratory motion. However, this problem still remains unsolved for practical purpose. The scientific-research organizations must intensify their research in order to develop a reciprocating electric motor and auto-oscillating systems with a simple system for the control of oscillation amplitude and frequency.

Studies of systems containing elastic members can be of great interest to the theory and practice of electric drives. At present all members of a system are considered as being ideal solid bodies and, therefore, processes in which deformations are of importance are not considered at all. Deformations of elastic members often lead to considerable errors. In connection with this, it seems

expedient to work out general methods of analysis for automatic control systems containing elastic members, and to solve the problem of synthesis of electric drives and drive-control systems for mechanisms with elastic members.

Certain theoretical problems of heating in electric drive still remain unsolved, although this theory has advanced considerably during recent years. For example, further study of the processes of heating of a-c motors for normal operating conditions, including asymmetrical feeding of three-phase asynchronous motors is needed. Further investigation should be made of problems of electric motor heating in transient processes and during cycling loading, taking the aging of the insulation into account. The study of direct application of the heat-conduction equations to thermal calculations for electric motors should also be continued.

Many problems of the micro-drive must be solved. This field has been studied very little, although it is expanding rapidly. Millions of electric motors will be needed in the next few years for micro drives. In this connection it is necessary to continue the development of economical systems for existing micro-drives and the improvement of their reliability and quietness and precision and also to increase the response speed of the micro-drives applied in automation systems.

A tremendous role is being played by the modern electric drives in automation systems for production processes. Especially important is the programmed control of the electric drives of separate mechanisms and aggregates. Some success has recently been achieved in the introduction of programmed control systems into a number of metal-working mills, the pressure mechanisms of reversing rolling mills, and electric drives for blast-furnace charging, etc. But the general state of work in the field of developing and widening the application of programmed control is unsatisfactory. New automation equipment (semiconductor and magnetic elements) is seldom used and the latest achievements in self-adjusting and self-instructing systems are reflected very little. As a rule the programming systems presently in use are operating on :. rigid programs which do not always satisfy the technical specifications for the process under conditions of varying external disturbances. Application of systems which are able to correct the program automatically in accordance with changes in the external influences on the operation of the aggregate will render possible the most efficient regimes of operation.

An important obstacle to wider application of

automatic control in mechanisms equipped with electric drives is the imperfection of the existing positioners of the machine elements and the processed material. Another handicap is the imperfection of the relay-contact devices, which withstand only a limited number of switchings. The number of switchings of contacts in automatic machinery lines reaches tens of thousands or sometimes hundreds of thousands per hour, which drastically reduces the reliability of electrical control systems. In connection with this, the application of contactless automatic control devices using the highly reliable semiconductor and magnetic elements is gaining great importance.

Electrical apparatus used in communication systems is not used to the proper extent in control schemes of electrical drives in a number of industrial processes. It is necessary to use these devices, which have small dimensions and high reliability, on a larger scale.

In order to accelerate the mass application of modern automatic electric-drive control systems, the electrical industry must quickly familiarize itself with the standard elements of the new control systems, including digital and programming systems as well as complete control systems for standard electric drives.

This listing of problems in the field of electric drives is far from complete and encompasses only the problems of highest urgency.

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